MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

EEE1016 – ELECTRONICS I

(All Sections / Groups)

7 FEBRUARY 2023
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **10** pages including the cover page and Appendix. There are **FOUR** questions in this paper.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of marks for each question is given.

3. Some useful formulae are given in the Appendix section (see Page 9–10).

4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Identify **TWO** statements that are **TRUE**:

A. According to the Mass Action Law, under thermal equilibrium, the product of free negative and positive concentrations is a constant independent of the amount of donor and acceptor impurities.

B. Electron-hole pair generation means when a valence electron is thermally excited into the conduction band and leaves behind a positive charge.

C. Antimony (Sb) atom has an atomic number of 51. In ascending order of energy, the electron configuration for Sb is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^3$. The Sb atom has 5 electrons in its outermost shell.

D. A pure silicon (Si) semiconductor has an intrinsic carrier concentration of 1.85×10^{10} cm^{-3}. The Si material is doped with arsenic (As) atoms at a concentration of 7×10^{10} cm^{-3}. Therefore, the electron concentration of the extrinsic semiconductor is 8.85×10^{10} cm^{-3}.

[2 marks]

(b) P-type extrinsic semiconductor materials are produced from the controlled addition of acceptor impurities to the intrinsic (pure) semiconductor. Table Q1(b) presents a list of elements and their atomic numbers.

From Table Q1(b), determine the following:

- **ONE** element for the intrinsic semiconductor; and
- **ONE** element for the acceptor impurities.

For the selected elements, state their electron configurations. [4 marks]

Table Q1(b)

Element	Atomic number, Z
A	7
B	13
C	29
D	32
E	48

Continued...

Question 1

(c) At $T = 300°K$, a sample of intrinsic (pure) germanium (Ge) has an intrinsic carrier concentration of 2.5×10^{13} cm^{-3}. The Ge material is doped to the extent of 4×10^{13} donor atoms/cm^3 and 1×10^{14} acceptor atoms/cm^3. Given that the electron and hole mobilities of Ge are $\mu_n = 3900$ cm^2/V-s and $\mu_p = 1900$ cm^2/V-s, respectively.

(i) Determine the electron and hole concentrations of the extrinsic Ge material. [7 marks]

(ii) Find the drift current density of the extrinsic Ge, for an applied electric field of 85 V/cm. [3 marks]

(d) Referring to the diode circuit in Figure Q1(d), the silicon (Si) p-n junction diodes (D1, D2) have cut-in voltage $V_\gamma = 0.76$ V and forward diode resistance $R_f = 18\ \Omega$. The voltage of Zener diode D3 (when reverse biased) is $V_Z = 5.7$ V.

(i) Draw the piecewise-linear diode equivalent circuit. [2 marks]

(ii) Find the current I. [3 marks]

(iii) Calculate the voltage drop across the load resistor R_L. [2 marks]

(iv) Determine the value of R_S that limits the current I to 35 mA. [2 marks]

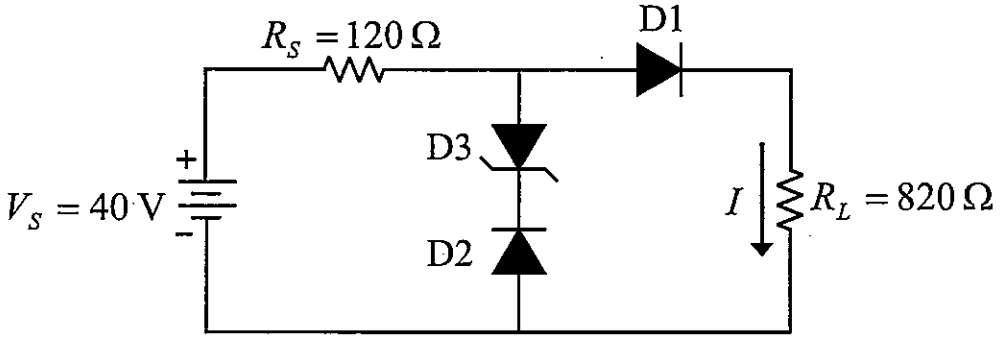

Figure Q1(d)

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Question 2

(a) Figure Q2(a) depicts a single-phase half-wave rectifier circuit with an input signal $V_{in} = 15\sin(200\pi t)$ V. Given that the load resistance $R_L = 1$ kΩ. Assume the diode has a cut-in voltage $V_\gamma = 0.7$ V, and the forward diode resistance R_f is negligible.

Determine the following:

(i) Average output voltage $V_{o(av)}$ [2 marks]

(ii) Average load current $I_{o(av)}$ [2 marks]

(iii) Root-mean-square (RMS) output voltage $V_{o(rms)}$ [2 marks]

(iv) RMS load current $I_{o(rms)}$ [2 marks]

(v) Ripple factor of the output voltage, γ [2 marks]

(vi) Average power through the load R_L, $P_{o(dc)}$ [2 marks]

(vii) Power absorbed by the load R_L, $P_{o(rms)}$ [2 marks]

(viii) Rectification efficiency, η [2 marks]

(ix) Sketch the input and output waveforms (i.e., V_{in} and V_{out}) for $0 \le \omega t \le 2\pi$, clearly indicating the values of the respective amplitudes. [3 marks]

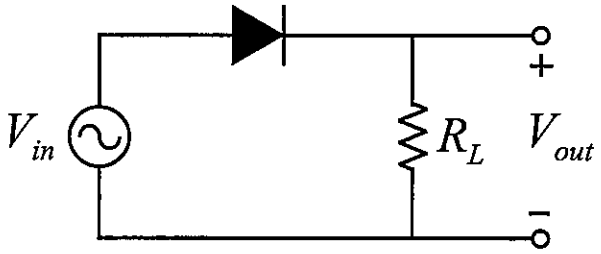

Figure Q2(a)

Continued...

Question 2

(b) Figure Q2(b) shows a parallel clipping circuit with an input signal $V_{in} = 18\sin\omega t$ V. Assume the diodes have cut-in voltage of 0.7 V.

(i) Calculate the maximum and minimum output voltages. [3 marks]

(ii) Sketch the input and output waveforms (i.e., V_{in} and V_{out}) for $0 \le \omega t \le 4\pi$, clearly indicating the values of the respective amplitudes. [3 marks]

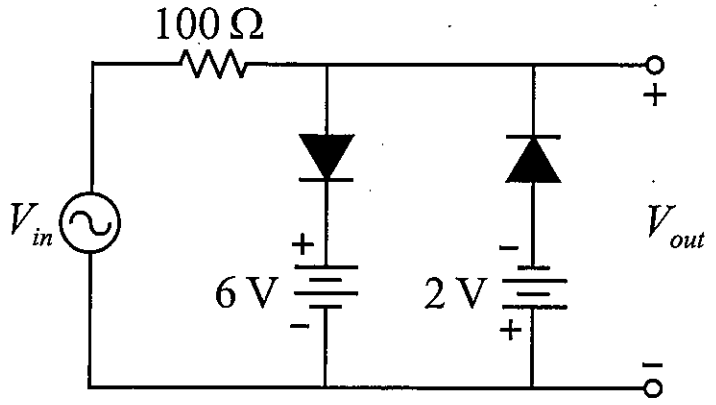

Figure Q2(b)

Question 3

(a) Bipolar junction transistors (BJTs) can be operated in **FOUR** different biasing modes, depending on the biasing polarities of the emitter-base (E-B) and collector-base (C-B) junctions. Fill in the blanks for Table Q3(a).

[6 marks]

Table Q3(a)

Biasing Mode	Biasing Polarity (E-B Junction)	Biasing Polarity (C-B Junction)

Continued...

Question 3

(b) Figure Q3(b) illustrates an emitter-stabilised bias transistor circuit, with $R_C = 2.2$ kΩ, $R_B = 620$ kΩ, and $R_E = 750$ Ω. Given that the DC amplification factor $\beta = 150$, $V_{CC} = 30$ V, and $V_{BE} = 0.7$ V.

(i) Find the base and emitter currents, I_B and I_E. [4 marks]

(ii) Calculate the base voltage, V_B. [2 marks]

(iii) Determine the Q-point parameters, I_{CQ} and V_{CEQ}. [4 marks]

(iv) Calculate the DC load line parameters, $I_{C(sat)}$ and $V_{CE(cutoff)}$. [3 marks]

(v) Determine the power dissipated in the transistor. [2 marks]

(vi) Draw the common-emitter (C-E) output characteristic (i.e., I_C versus V_{CE}). In your sketch, show the DC load line, Q-point, $I_{C(sat)}$ and $V_{CE(cutoff)}$. [4 marks]

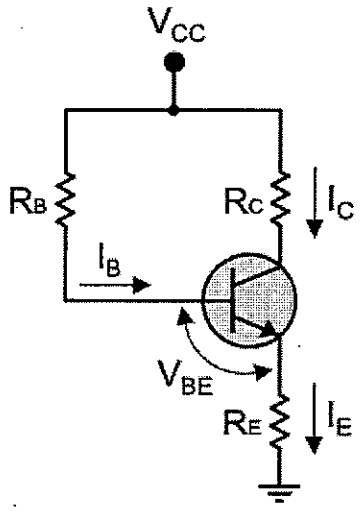

Figure Q3(b)

Continued...

Question 4

(a) Figure Q4(a) shows a common-emitter bipolar junction transistor (BJT) amplifier circuit. Draw the small signal equivalent circuit of the transistor amplifier using the transistor models below. In each drawing, you must clearly label the circuit components and indicate the AC elements of i_b, i_c, v_{be} and v_o.

(i) The *h-parameter* model. [3 marks]

(ii) The hybrid-π model. [3 marks]

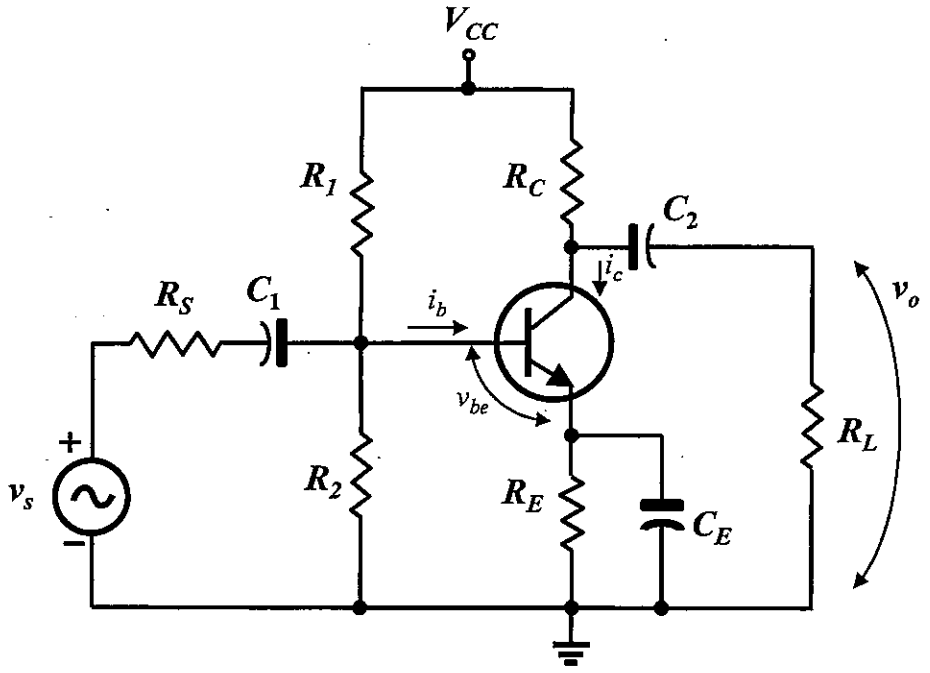

Figure Q4(a)

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Question 4

(b) The transistor amplifier circuit in Figure Q4(a) has load resistance R_L = 1.5 kΩ and a source resistance R_S = 330 Ω. Assuming an operating temperature of 27°C, the thermal voltage is V_T = 26 mV. The relevant parameters of the amplifier circuit are provided as follows:

Biasing Components	
DC Supply, V_{CC}	36 V
Bias resistance, R_1	330 kΩ
Bias resistance, R_2	33 kΩ
Collector resistance, R_C	6.8 kΩ
Emitter resistance, R_E	4.7 kΩ

Transistor Parameters	
Current gain, β	220
Early Voltage, V_A	75 V
Base-emitter voltage, V_{BE}	0.7 V

Coupling and By-Pass Capacitors	
$C_1 = C_2 = C_E$	10 μF

(i) Construct the small-signal r_e model of the transistor amplifier, and show all the known values of its components. [3 marks]

(ii) Using the approximation method, determine the following:

- The base voltage, V_B
- The emitter current, I_E
- The base-emitter resistance, βr_e [6 marks]

(iii) Calculate the input impedance Z_{in} and the effective input impedance Z_{in}', as seen from the signal generator. [4.5 marks]

(iv) Determine the voltage gain of the amplifier, $A_v = \frac{v_o}{v_i}$. [5.5 marks]

End of Question

APPENDIX

1. Charge of electron, $q = 1.6 \times 10^{-19}$ coulomb
2. Mass of electron, $m = 9.11 \times 10^{-31}$ kg
3. Holes and electrons in pure semiconductor, $p = n = n_i$
4. Law of Mass-action, $np = n_i^2$
5. Law of Electrical Neutrality, $\left(N_D^+ + p\right) = \left(N_A^- + n\right)$

   When all imprurities are ionised, $\left(N_D + p\right) = \left(N_A + n\right)$
6. In *n-type* semiconductor, $n_n \approx N_D$. In *p-type* semiconductor, $p_p \approx N_A$
7. Drift current density, $J_{drift} = J_n + J_p = \left(n\mu_n + p\mu_p\right)qE = \sigma E$
8. Characteristics of common semiconductors

Semiconductor	Intrinsic carriers/cm^3	μ_n (cm^2/V-s)	μ_p (cm^2/V-s)
GaAs	1.7×10^6	8500	400
Si	1.5×10^{10}	1350	410
Ge	2.5×10^{13}	3800	1800

9. Shockley diode equation, $i = I_o\left(e^{\left(\frac{V}{\eta V_T}\right)} - 1\right)$ where $V_T = \frac{kT}{q} = 26\text{mV}$
10. Form factor of rectifier, $FF = \frac{V_{o(rms)}}{V_{o(av)}}$
11. Ripple factor of rectifier, $\gamma = \sqrt{\left(\frac{V_{o(rms)}}{V_{o(av)}}\right)^2 - 1} = \sqrt{FF^2 - 1}$
12. RMS output voltage of half-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{2}$
13. RMS output voltage of full-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{\sqrt{2}}$
14. Average output voltage of half-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{V_{o(p)}}{\pi}$

15. Average output voltage of full-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{2V_{o(p)}}{\pi}$

16. Average output current of full-wave rectifier, $I_{o(av)} = I_{o(dc)} = \frac{2I_{o(p)}}{\pi} = \frac{2V_{o(p)}}{\pi R_L}$

17. Power dissipated at the load, $P_{(dc)} = I_{dc}^2 R_L$ and $P_{(rms)} = I_{rms}^2 R_L$

18. RMS output current of full-wave rectifier, $I_{o(rms)} = \frac{V_{o(rms)}}{R_L}$

19. Efficiency, $\eta_{\max} = \frac{P_{dc}}{P_{rms}}$

20. Internal emitter resistance of BJT, $r_e = \frac{V_T}{I_E} = \frac{26\text{mV}}{I_E}$

21. Internal output resistance of BJT, $r_o = \frac{V_A}{I_C}$

End of Paper